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# JOURNAL

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## INSTITUTE OF ACTUARIES.

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*On the Arrangement of the Data furnished by certain Life Assurance Companies in Scotland, and on the formation of Tables, &c., therefrom; being Contributions towards the ascertainment of the Rate of Mortality of Assured Lives. By JAMES MEIKLE, Esq., Actuary of the Scottish Provident Institution.*

[Read before the Institute, 17th December, 1866.]

THE mortality statistics of the Scottish Assurance Offices, whose experience it is proposed to develop before combining it with that of the English contributing Offices, have, after passing through various committees, and receiving the benefit of their consideration, eventually passed into my hands for final adjustment and development. Having accordingly considered the subject thus confided to my professional care, I venture to lay before the Institute a brief statement of the views which have occurred to me in regard to the processes which it is proposed to adopt for the arrangement of these data and transforming them into that shape which it is necessary they should assume before becoming the subject of comparison or of calculation.

The data of each Scottish contributing Company have, it is well known, been furnished upon cards, and consist of the name of the life and the amount assured, the date of birth, the date and age of entry, and the date and age at exit—that is, at the termination of the risk, which may either be that of cancellation, death, or that of the date of investigation, viz., 31st December,

1863.\* The cards of deaths were marked by a D, on a special part of the card; and the cancelled by either an S (the initial letter of surrendered) or an L (lapsed); and those which were in existence at 31st December, 1863, were marked by a light stroke, thus —. White cards were used for males, and pink for females.

Under the impression that experience in this matter was of the greatest importance, I made several experiments with the cards of my own Office, and with those of the Offices which were earliest placed in my hands. The result of these experiments was such as I have every reason to believe, that the process followed with the smaller number of cards of one Office might with at least equal advantage be applied to the entire cards of the ten Scottish contributing Offices. On examining the processes which had been followed in similar investigations based upon the card system, it occurred to me that considerable difficulty would attend the counting and balancing the cards for so large a number as 120,000 lives, when in the first place arranged according to *ages at entry*, and in the second rearranged according to *ages at exit*. I have, however, fallen upon a plan for classifying the cards in small numbers which suits admirably; and not only does it suit in regard to the mere matter of *counting* the cards, but it affords the means of *checking* the accuracy of the calculations, and it also affords the means of showing the *effects of selection*, and the depreciation of life after the benefits of selection have worn off. All of these I shall now try to explain.

It was at first thought that *one* card, representing the continuous experience for each life, would be sufficient, and printed instructions were issued to that effect. I perceived, however, that it was quite possible for *one* life to embody the facts of many experiences, each of which would be represented by each of the policies. These earliest instructions were accordingly altered, and I asked from the Offices a card for each policy except in those cases where they were opened at the same date and were in other matters identical. It was customary, previous to the change in the stamp laws, for one life to open two policies for half the sum assured, for the purpose of saving the difference between the stamp for the full amount and the two stamps for the two halves. In any such case *one* card would sufficiently represent the experience. And in other

\* If there had been any intention of continuing the experience of the same number of entrants, and the opportunity seems an excellent one, it would only have been necessary to have noted the issue of those policies which had terminated by cancellation or by death. Each of the contributing Offices would thereafter only be required to give a note on slips of paper of the policies which had, out of the entrants previous to 1864, become cancelled or dead.

cases, nearly similar perhaps, one card would be sufficient. At all events the Offices have not been requested to curtail the number of cards ; I have rather asked a card for each policy. Each Office was further asked to note the numbers of all the policies on the same life on each card, so as to act as a guide and check in collecting the total number of cards issued on each life. This has been very carefully done by one or two Offices, but others have made no attempt in the matter, and have thereby greatly increased the consequent labour.

When put in possession of the cards of any Office my first step was to classify them according to the first letter of the *name*. When the cards were thus sorted they were carefully *banded* and laid aside. Each letter was then taken up by itself, and classed according to the *second* letter, and also to the *third* letter ; any error in the first or second arrangements being checked in the second or third. Each of these small sections was then taken up and the cards classified according to surnames and to christian names, and thereby the cards belonging to each life were brought together. The *date* of birth being given in the Scotch cards, I judged it to be quite conclusive when the names and the dates of birth were the same, that they referred to the same life. There have been curious instances of approaching similarity, but of different identity, which, if I had had time, it would have been interesting to have noted. It is also most important that a lady's maiden name should be given along with her husband's. There are other modes of recognising the identity than the date of birth. The date of death, or the cause of death ; or one policy may be opened on the same date as the lapsing of a former policy, or the same kind of climate extra, or other points which occur to the mind of the classifier. When it was suspected that two or more cards referred to the same life, but which differed in some essential point, they were taken to the Office for adjustment or correction. In place of writing out a new card for each life, I instituted an envelope capable of containing the cards referring to the same life, and printed in the same way as the cards. On the envelope the facts of the *continuous* experience of the life were noted. When the risks on the life were not continuous, the cards were dismissed with a jotting referring to each other, thus—

Previous risk,  $\frac{35}{40}$  ;

and Risk repeated,  $\frac{45}{50}$  ;

in case it might be necessary to collect these cards again. The flap of the envelope was carefully laid inside, so as to be out of the way in sorting, and at same time so as to afford access to the separate cards.

When the whole cards were gone over they were redistributed according to the *ages at entry*, and it is the distinguishing feature of my process to retain them in this form for all further use. In the first place it is important to make sure that the cards of each of these lots refer to the same age at entry. A check on this is obtained in the second distribution—by making the distributor look at *two* things—that is, in distributing them according to — (existing), L (lapsed), or D (dead), to see that they are all

35 —,  
35 L,  
or 35 D.

I even recommend that the figures be spoken, which I imagine adds to the security of the check, although it is not an infallible safeguard. But as the process of classification of the same lot of cards has to be performed so frequently, there is no risk of any continued error. The cards of the entrants at each age are now in three divisions—the living, the dead, and the discontinued, the sum of which is the number of the entrants at that age. Each parcel is banded, and the three are again banded in one with a stronger band.

The next part of the process is that which may be called “tabulating the facts.” The parcel of cards belonging to each age at entry is taken up, and each of its parts classified separately and tabulated in the following form. (See next page.)

The classification is checked thus:—

The first arrangement is in accordance with the *age at exit*. The cards of each parcel are gone over, counted, and tabulated. The same lot are gone over again while lying on the desk, but while counting their number with the lips the eye this time rests on the fact whether all those who exit at  $x+0$  have 0 for the years of duration, and those who exit at  $x+1$  have all 1 for years of duration, &c. &c. I have found this check a very valuable one, measuring its value by the number of errors discovered. The same process is gone over for the existing, discontinued, and the dead of each age at entry, and the number of entrants— $m_x - (\Sigma c_{x+n} + \Sigma d_{x+n} + \Sigma l_{x+n})$  is the result of a *summation of figures in ink*, which is much more to be relied on than the more ethereal one of counting cards

*Assured-life Experience to 31st December, 18—. (Current Age at Entry, 30.)*

n.	x+n.	m <sub>x+n</sub>	Of whom		Sum of Numbers in Cols. 4, 5, 6.		Sum of Col. 7.		Number exposed to Mortality.		Completed Age on entering Year of Risk.	Number of Deaths.
			Cancelled	Died	Living at 31st Dec., 18-	at Age in Col. 2.	(c <sub>x+n</sub> + d <sub>x+n</sub> + l <sub>x+n</sub> )	(c <sub>x+n</sub> + d <sub>x+n</sub> + l <sub>x+n</sub> )	x+n-1.	Col. 8 + Col. 9.		
1.	2.	1,083	5	3	78	86	997	997	29	539*	3	2
2.	3.	..	88.	2	62	152	845	845	30	953*	9	5
3.	4.	..	54.	9	65	128	717	717	31	818	2	9
4.	5.	..	45.	5	67	117	600	600	22	694.5	5	2
5.	6.	..	26.	2	55	83	517	517	13	587.	2	2
6.	7.	..	18.	1	59	78	439	439	9	508.	1	1
7.	8.	..	12.	5	51	68	371	371	6	433.	5	5
8.	9.	..	29.	2	35	66	305	305	14.5	356.5	2	2
9.	10.	..	5.	3	42	50	255	255	2.5	302.5	3	3
10.	11.	..	1.	2	37	40	21.5	21.5	5	254.5	2	2
11.	12.	..	1.	3	37	41	17.4	17.4	5	214.5	3	3
12.	13.	..	3.	3	34	37	13.7	13.7	1	174.	3	2
13.	14.	..	2.	2	42	46	9.1	9.1	5	136.	2	2
14.	15.	..	1.	1	32	33	58	58	1	42	90.5	1
15.	16.	..	2.	1	25	28	30	30	1.	43	57.	1
16.	17.	..	1.	1	15	16	14	14	..	44	30.	1
17.	18.	..	6.	..	5	6	8	8	..	45	14.	1
18.	19.	..	48.	..	2	2	6	6	..	46	8.	1
19.	20.	..	49.	..	4	4	..	..	..	47	6.	1
20.	21.	..	50.	..	1	1	2	2	..	48	2.	1
21.	22.	..	51.	..	..	..	1	1	..	49	1.	1
22.			52.	..	..	..	1	1	..	50	1.	1
		1,083 =	289	+ 45	+ 749	1,083	5,784	5,784	+ 541.5	=	6,181	45
						$\frac{1,083 - 5}{2} = + 539$			$-\frac{144.5}{2} + 397$	=		$\frac{397}{6,181} =$

**Note.**—Since the above was written I have thought it right to add two columns rearranging the deaths, so as to be able to compare the possible years of life enjoyed with the years actually enjoyed.

in the air. The materials have thus been obtained for ascertaining the number exposed to risk of mortality out of all those who entered at each age. This is worked up from the formula—

$$\text{Number exposed to mortality at completed age } (x+n-1) = m_x - \sum_{x+n-1} (c_{x+n} + d_{x+n} + l_{x+n}) + \frac{m_{x+n} - c_{x+n}}{2}$$

and  $\frac{\text{deaths } (x+n-1)}{\text{No. exposed } (x+n-1)} = \left\{ \begin{array}{l} \text{Rate of mortality from} \\ \text{age } x+n-1 \text{ to age } x+n. \end{array} \right.$

The summation of the number exposed for each age at entry is checked from the totals of the other columns, as shown in the foregoing example.

The tables in their present shape appear to me to be most valuable. They exhibit the light mortality following selection, and also the heavier mortality of lives long exposed—two points which I have had very great anxiety to see developed. I imagine, however, that for both objects these partial tables are incomplete, as afterwards referred to; and that at their present stage they are only parts of an entire average table of mortality for all ages, such as it has hitherto been the practice to develop. I do not doubt that it is possible to deduce *one* table which shall fairly represent assured-life experience based upon an average rate of mortality for each age of life, but I intend to be sceptical upon the point, and to observe how widely the actual progressive rate of mortality deviates on either side of the average, and then to make up my mind whether it would be prudent to frame tables of annuities, &c., applicable to each age of entry. Hitherto I have not seen any grounds for believing that the rate of mortality is to be considered as *constant* at each age. It is exceedingly convenient to make that assumption, but I think it is doubtful whether it is safe to do so, especially when taken in connection with some of the present modes of withdrawing profit. However, this doubt, it will be understood, is, in the meantime, a *crochet* of mine, as well as, I believe, of some others.

I have now to explain how I propose to frame a mortality table from these minor or partial tables. The numbers *entering* at each age in the partial tables are the same as those *entering* in the complete or average table; but for the number discontinued, died, or living in the average table, the items of these classes are, on three large sheets of paper ruled conveniently for the purpose, recast according to the ages attained in year of cancellation, year of death, or at 31st December, 1863, if surviving; the form of which is obvious, but I annex one as a specimen:—

*Discontinued—Recast according to Ages at Exit.*

Current Age at Entry.	No. Cancelled.	Current Age at Exit.															
		20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.
20	127	1	38	59	9	6	8	2	4	...	...	1	...	...	...	...	...
21	169	..	7	112	17	8	11	5	3	8	...	3	...	1	...	1	...
22	170	..	..	4	56	34	28	13	11	10	8	3	...	1	1	1	...
23	168	..	..	..	7	55	40	26	14	7	4	6	2	3	3	3	1
24	210	..	..	..	..	4	86	33	28	23	13	8	4	5	2	..	3
25	222	..	..	..	..	..	6	67	37	32	21	20	13	13	4	6	2
26	226	..	..	..	..	..	..	4	83	39	34	10	18	7	12	6	3
27	266	..	..	..	..	..	..	7	86	48	27	26	19	16	16	7	..
28	263	..	..	..	..	..	..	..	..	890	49	30	18	12	20	16	..
29	282	..	..	..	..	..	..	..	..	..	1	81	60	38	18	16	18
30	289	..	..	..	..	..	..	..	..	..	5	88	54	45	26	18	..
31	275	..	..	..	..	..	..	..	..	..	..	2	86	65	34	18	..
32	283	..	..	..	..	..	..	..	..	..	..	..	4	73	48	43	..
33	276	..	..	..	..	..	..	..	..	..	..	..	..	5	89	52	..
34	290	..	..	..	..	..	..	..	..	..	..	..	..	..	7	85	..
35	276	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..
36	271	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
37	277	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
38	264	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
No. discontinued} at each Age }		102	119	184	158	188	212	219	210	243	248	255	269	271			

These are summed up, and the totals made to agree with the totals of the partial tables. The same process having been gone over with the deaths and the living, the materials are obtained for working up the average or entire table of mortality after the same formula—

$$\text{Number exposed at age } x-1 = \Sigma_{x-1} m_x - \Sigma_{x-1} (c_x + d_x + l_x) + \frac{m_x - c_x}{2},$$

which may be further checked by recasting the number exposed to risk for each of the minor tables. This completes the labour, and it may with confidence be maintained that the average table, as well as set of minor tables, are correct.

Some interesting checks may be obtained by preparing tables based upon the totals of the average or complete table and the totals of the partial or minor tables, which will prove eminently satisfactory and complete.

Thus, by forming the products of  $xm_x$ ,  $xc_x$ ,  $xd_x$ , and  $xl_x$ , then

$$\frac{\Sigma x.m_x}{\Sigma m_x} = \text{average age at entry of all,}$$

$$\frac{\Sigma x.c_x}{\Sigma c_x} = \text{average age at entry of the policies;}$$

and other results which are quite apparent to the ordinary computer.

## I.—Extract from complete Table, deduced directly from the Entrants, Discontinued, Died, and Existing at each Age.

Current Age at Entry.	$m_x$ .	$c_x$ .	$d_x$ .	$l_x$ .	$c_x + d_x + l_x$ .	$\Sigma_{x-1} (c_x + d_x + l_x)$ .	$\Sigma_{x-1} m_x$ .	Difference.	$\frac{m_x - c_x}{2}$ .	Number exposed.
26	710	158	14	181	353	1,970	3,529	1,559	276	1835
27	878	188	16	266	470	2,323	4,239	1,916	345	2261
28	910	212	28	286	526	2,793	5,117	2,324	349	2673
29	1,000	219	24	332	575	3,319	6,027	2,708	390	3098.5
30	1,083	210	22	339	571	3,894	7,027	3,133	436	3569.5
31	1,059	243	31	379	653	4,465	8,110	3,645	408	4053
32	1,073	248	41	428	717	5,118	9,169	4,051	412	4463.5
33	1,123	255	27	489	771	5,835	10,242	4,407	434	4841

## II.—\*Extract from complete Table, deduced from the minor Tables recast.

Years of Assurance.	PASSING THROUGH AGE									
	27.		28.		29.		30.		31.	
	No. Exposed.	Deaths.	No. Exposed.	Deaths.	No. Exposed.	Deaths.	No. Exposed.	Deaths.	No. Exposed.	Deaths.
0	435.5	1	451.	..	499.5	5	539.	3	528.5	2
1	618.5	5	765.	9	775.	4	885.5	5	953.	2
2	511.5	6	499.5	6	635.	7	631.5	4	767.	8
3	256.	..	411.	4	412.	4	540.5	4	528.	7
4	169.	1	205.5	1	342.5	2	344.	3	455.	9
5	128.5	1	133.5	4	171.5	1	281.	..	301.	..
6	49.5	1	99.	1	104.	..	139.	1	237.5	1
7	29.	1	33.5	1	75.	..	87.	1	119.	1
8	19.	..	25.	2	30.	..	57.5	1	69.	..
9	11.	..	18.	..	20.	..	26.5	..	49.	1
10	8.5	..	7.	..	12.	1	16.	..	21.	..
11	16.	..	8.	..	5.	..	9.	..	13.	..
12	6.	..	14.	..	7.	..	4.	..	7.	..
13	3.	..	1.	..	8.	..	4.	..	1.	..
14	..	..	2.	..	1.	..	3.	..	2.	..
15	..	..	..	..	1.	..	1.	..	1.	..
16	..	..	..	..	..	..	1.	..	1.	..
Totals	2261.	16	2673.	28	3098.5	24	3569.5	22	4053.	31

It will thus be observed that little risk has been incurred in counting the cards. Being divided into comparatively small sections, the risk of error at first was not great: and after the counting had been repeated with reference to the years of duration, the risk almost disappears; and it will further be observed that I do not require to count the cards specially for the *entrants*. There is also, in many of the minor checks, and especially in the check obtained by the recasting of the tabulated facts of the minor tables,

\* The complete table, of which No. 2 is an extract, is in possession of the Institute.

a charm imparted to the calculation which excites the computer and carries him on with his work; and if the value of the minor tables be taken into consideration, I believe there is no increase of the labour; at all events it has appeared to me so insignificant as not to give me one moment's consideration.

I shall now point out the use I intend to make of the separate cards in the envelopes. As before referred to, I intend preparing a table of mortality for each age at entry, so far as the facts will avail, and thereafter, by means of some general assumption, to carry them on to the end of life. The minor tables before alluded to represent the experience of *lives* arising out of their *first policies*; and in that light they may be accepted by some actuaries as suitable for some kinds of assurance purposes. But I imagine that if any person, who assured at age  $x$ , assures again at  $x+5$ , that person is again a selected life at  $x+5$ , and ought also to appear among entrants of  $x+5$ , and the issue of each selection or entry appear in its own class; and so on at each of the ages at entry, so long as the same life does not appear twice in the same class. The separate cards in the envelopes will be taken out and placed each among entrants of the same age, and the facts retabulated, for the special purpose of showing the rate of mortality of entrants of each age. These tables are in themselves final. They cannot be recast for any average table except as a matter of fancy, or as showing the mortality among policies. They may, however, be recast according to years of assurance, either in decennial, quinquennial, or triennial periods, or the whole tables thrown together in one, and would, I imagine, present some very important features of mortality risks.

I annex two specimens, based upon the  $A_1$ ,  $A_2$ ,  $A_4$ , and  $A_5$  of Experience Tables. The *first* shows the number exposed to mortality in each year of assurance, passing through the two quinquenniums 35—40 and 40—45, together with the computed and the actual deaths in the same period of life. The *second* specimen throws the whole number (31,380) into years of assurance. The computed mortality is based upon the ratio of the number dying to the number exposed in each year of life in the usual way. Both tables illustrate very forcibly that the excess of the computed deaths in the early years of assurance (profitable) is balanced by the deficiency of the computed deaths in after years (unprofitable), and appear to me to possess great interest. They seem to indicate that life assurance valuations based upon an *average* table of mortality would require to be "corrected for selection."

Calen- dar Years of Assur- ance.	35-40.					40-45.				
	Number exposed.	Actual No. of Deaths.	Com- puted No. of Deaths.	Com- puted No. in excess.	Actual No. in excess.	Number exposed.	Actual No. of Deaths.	Com- puted No. of Deaths.	Com- puted No. in excess.	Actual No. in excess.
0	2626·5	17	26·4	9·4	..	2159·5	7	25·1	18·1	
1	4717·5	39	47·8	8·8	..	4036·5	37	46·9	9·9	
2	4142·	39	42·0	3·0	..	3462·	36	40·2	4·2	
3	3573·	27	36·1	9·1	..	3023·	33	35·0	2·0	
4	3033·5	33	30·6	..	2·4	2699·	37	31·5	..	5·5
5	2622·	33	26·4	..	6·6	2438·5	29	28·3	..	7
6	2194·	32	22·0	..	10·	2136·	34	24·8	..	9·2
7	1796·	23	18·1	..	4·9	1889·5	30	22·0	..	8·
8	1417·	16	14·3	..	1·7	1540·5	20	17·8	..	2·2
9	1124·5	12	11·3	..	·7	1269·5	19	14·7	..	4·3
10	840·	10	8·4	..	1·6	1080·5	15	12·6	..	2·4
11	605·	6	6·0	..	..	880·5	11	10·2	..	·8
12	389·5	4	3·8	..	·2	774·5	13	7·8	..	5·2
13	178·	2	1·7	..	·3	416·5	1	4·8	3·8	
14	71·	2	·7	..	1·3	210·5	2	2·4	·4	
15	29·5	1	·3	..	·7	95·	1	1·1	·1	
16	9·	0	·1	·1	..	38·	1	·4	..	·6
17	2·	0	·0	·0	..	15·	0	·2	·2	
18	..	..	..	..	..	9·	0	·1	·1	
19	..	..	..	..	..	4·	0	·1	·1	
20	..	..	..	..	..	3·	0	·0		
21	..	..	..	..	..	2·	0	·0		
Totals	..	296	296·	30·4	30·4	..	326	326·	38·9	38·9

Calen- dar Years of Assur- ance.	Number Exposed.	Actual Deaths.	Com- puted Deaths.	DIFFERENCE.		Total future Deaths provided for. Computed.	Total future Deaths provided by the computed by	Difference. The future actual Deaths being in excess of the com- puted by
				Computed Deaths in excess of actual.	Computed Deaths short of the actual.			
0	15605·5	108	189	81	..	2,482	2,482	0
1	27300·	302	342	40	..	2,374	2,293	81
2	22819·	307	296	..	11	2,072	1,951	121
3	19147·5	256	258	2	..	1,765	1,655	110
4	16155·	225	229	4	..	1,509	1,397	112
5	13860·5	232	205	..	27	1,284	1,168	116
6	11719·5	198	180	..	18	1,052	963	89
7	9778·	182	157	..	25	854	782	72
8	7944·	144	134	..	10	672	625	47
9	6648·	124	115	..	9	528	491	37
10	5485·	100	102	2	..	404	376	28
11	4445·5	86	86	..	..	304	275	29
12	3538·5	90	72	..	18	218	189	29
13	2291·	42	50	8	..	128	117	11
14	1244·5	34	29	..	5	86	67	19
15	653·	22	16	..	6	52	38	14
16	292·5	15	7	..	8	30	22	8
17	173·	5	5	..	0	15	15	0
18	107·	4	3	..	1	10	10	0
19	79·	2	2	..	..	6	7	- 1
20	57·	3	2	..	1	4	5	- 1
21	43·	..	1	1	..	1	3	- 2
22	33·	1	1	..	..	1	2	- 1
23	21·	..	1	1	..	..	1	- 1
Totals	169440·	2,482	2,482	139	139			

With reference to the *number of classifications* of the cards, I should like to see the following, but it is feared that I have proposed more labour than I shall conveniently be able to overtake:—

1. The entire cards.
2. The healthy } entire cards.
3. The diseased } entire cards.
4. The males } entire cards.
5. The females } entire cards.
6. With profits } entire cards.
7. Without profits } entire cards.
8. Those who have incurred risk of foreign climates.
9. Those who have not.
10. Above £1,000.
11. Under £1,000.
12. First year of assurance.
13. Experience of each age at entry.
14. Classification of the partial risks, in envelopes.

I should mention, however, that I have seen it necessary to make a separate class of earls, honourables, or peers' sons, or others who are likely to change their names in the course of the statistical period; and in the case of females it would be right to reclassify the cards according to the date of birth, although even that is not altogether a fixed point in a lady's history, but it may operate as a check against the double name to the same risk. Further, I would propose that the *deaths* be *reclassified* according to date of death, so as to make sure that no death has been counted twice—a matter of more importance than an open risk counted twice.

There are other matters to which I might allude, but in the meantime I confine myself to one point, viz., the desirableness of making no comparisons with tables calculated by methods which might, in the mere matter of calculation, give different results. That the *comparison of mortality* be complete, every other point ought to be the same—method of reckoning the ages, method of tabulating the facts, method of interpolation, &c. Overlooking these differences, a comparison may, of course, be made with any table, but it would be better if the tables were deduced by the same process.

